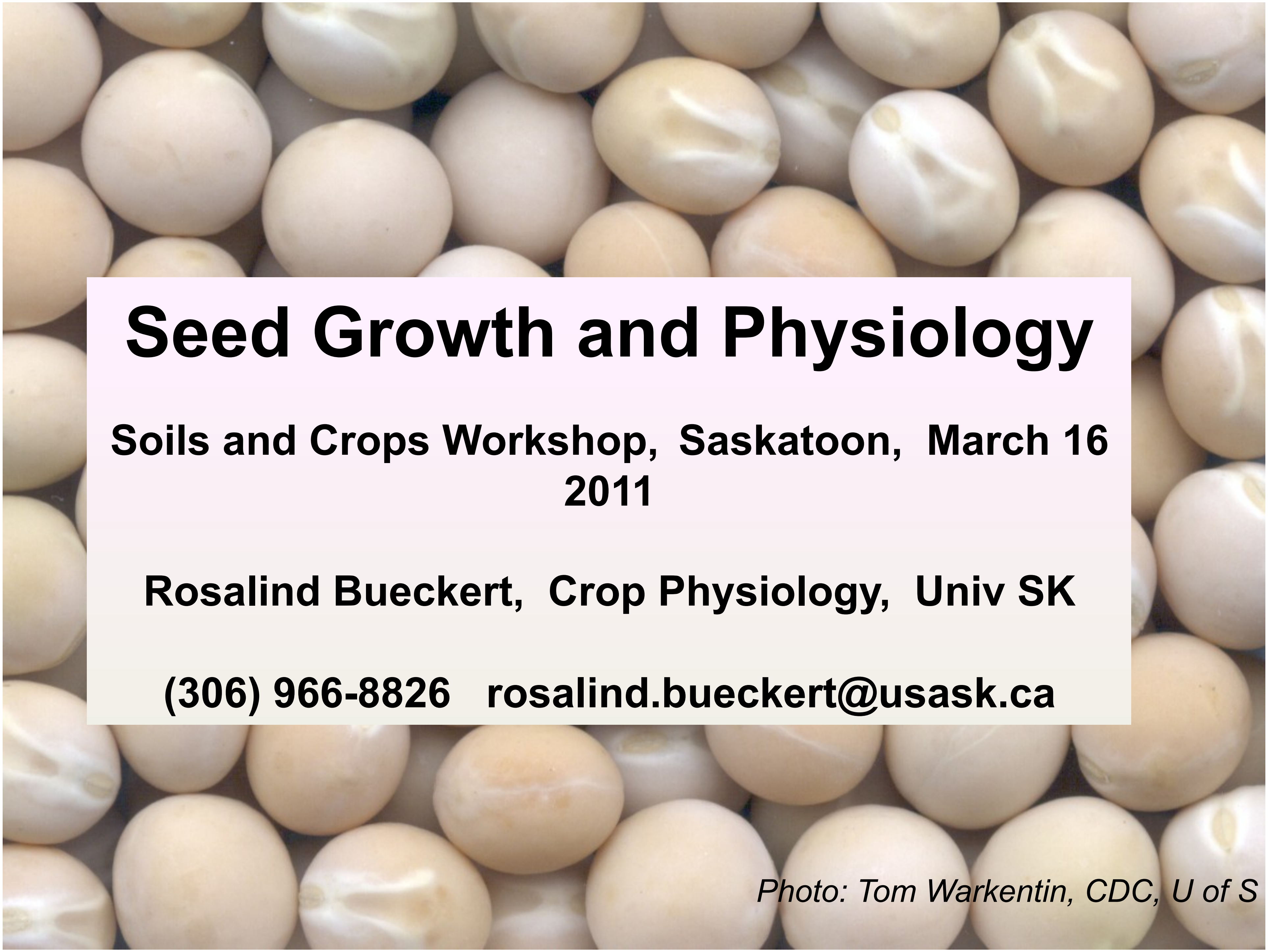


Seed Growth and Physiology

Soils and Crops Workshop, Saskatoon, March 16 2011

Rosalind Bueckert, Crop Physiology, Univ SK

(306) 966-8826 rosalind.bueckert@usask.ca

Photo: Tom Warkentin, CDC, U of S

OUTLINE

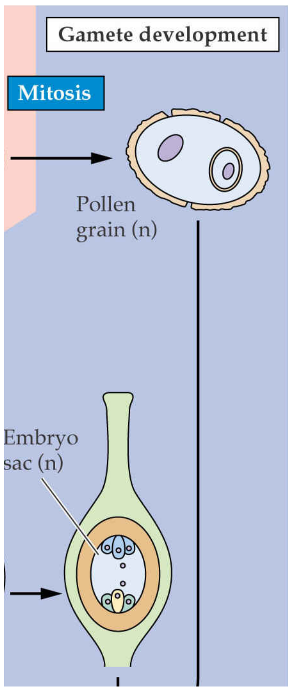
How seeds grow and why they achieve a certain size and vigor

SEED DEVELOPMENT

1. Flowering and fertilization
2. Seed development in Arabidopsis
   – plant physiology/ developmental biology
3. Seed growth in wheat- a field view
4. Seed development in soybean – the latest technology

CROP PHYSIOLOGY

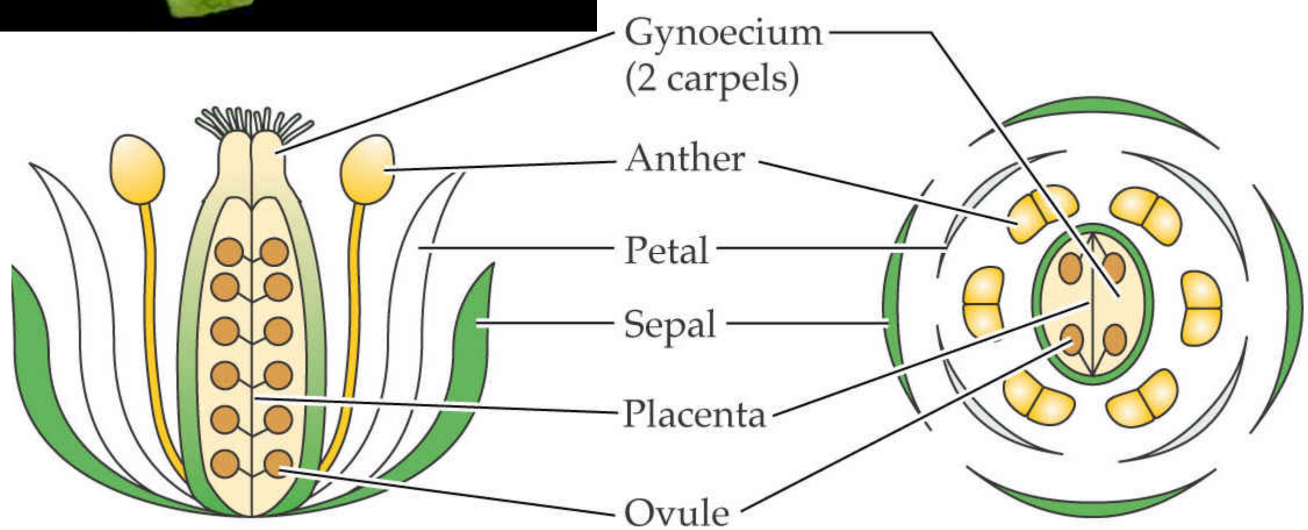
5. Seed growth in legumes
6. Seed size implications (and dormancy)



Arabidopsis flower

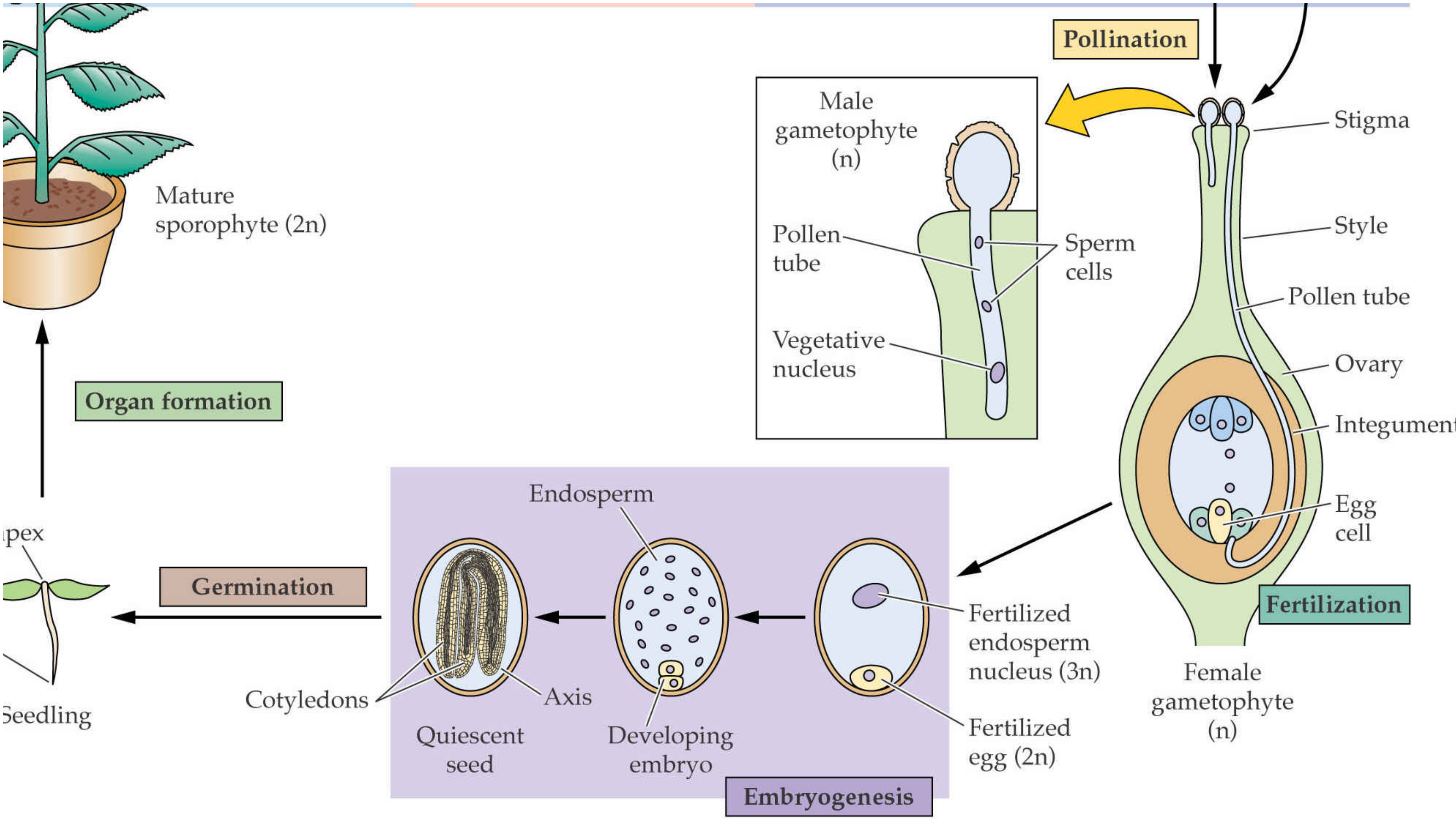
(Brassica- canola)

Self pollinates



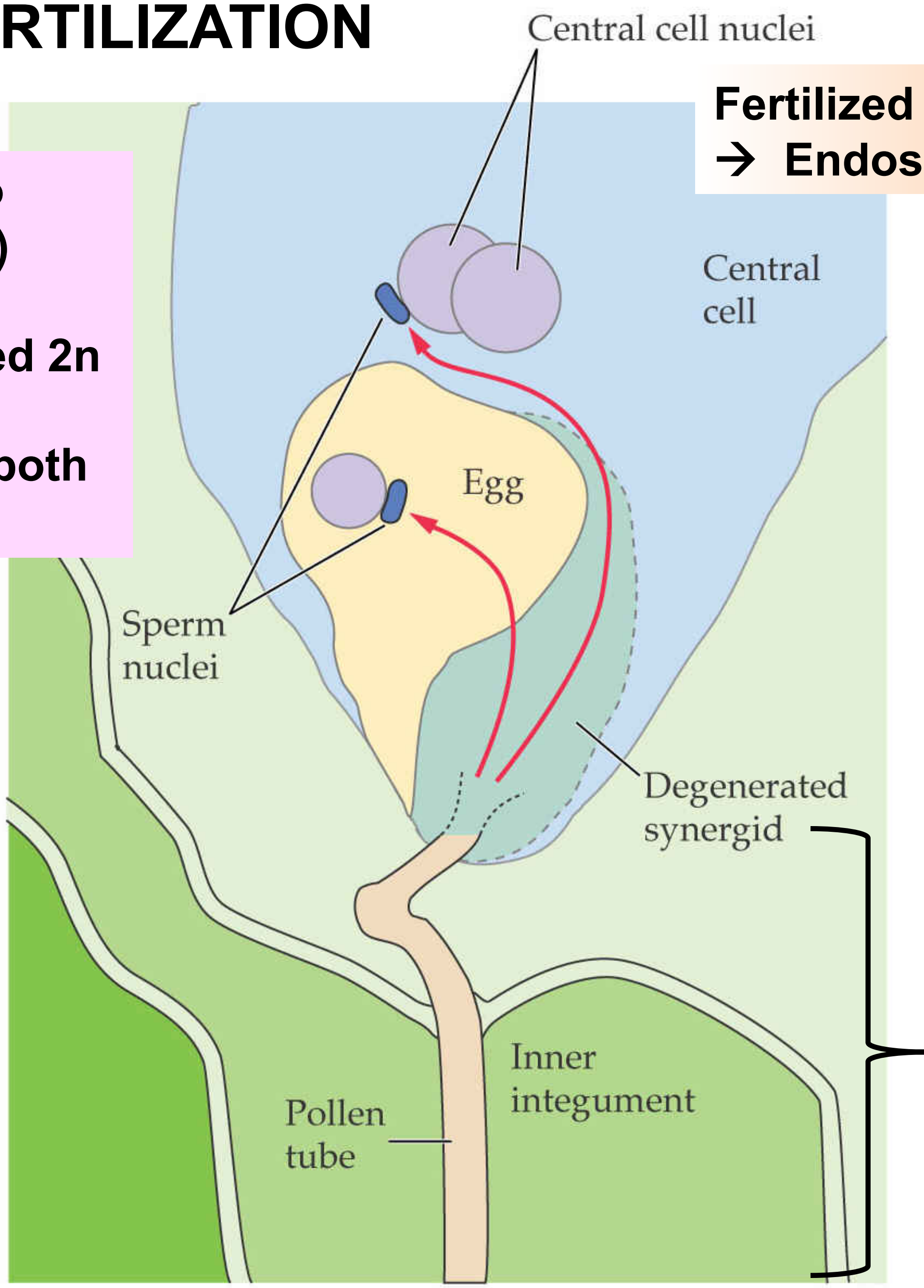
Upper picture – Robert Goldberg, UCLA
Lower picture – Buchannan et al text book

REVIEW OF FLOWERING AND FERTILIZATION – ANGIOSPERM



Biochem & Mol biol of Plants Buchannan et al 2000

DOUBLE FERTILIZATION



Embryo (zygote)

Fertilized 2n

n from both parents

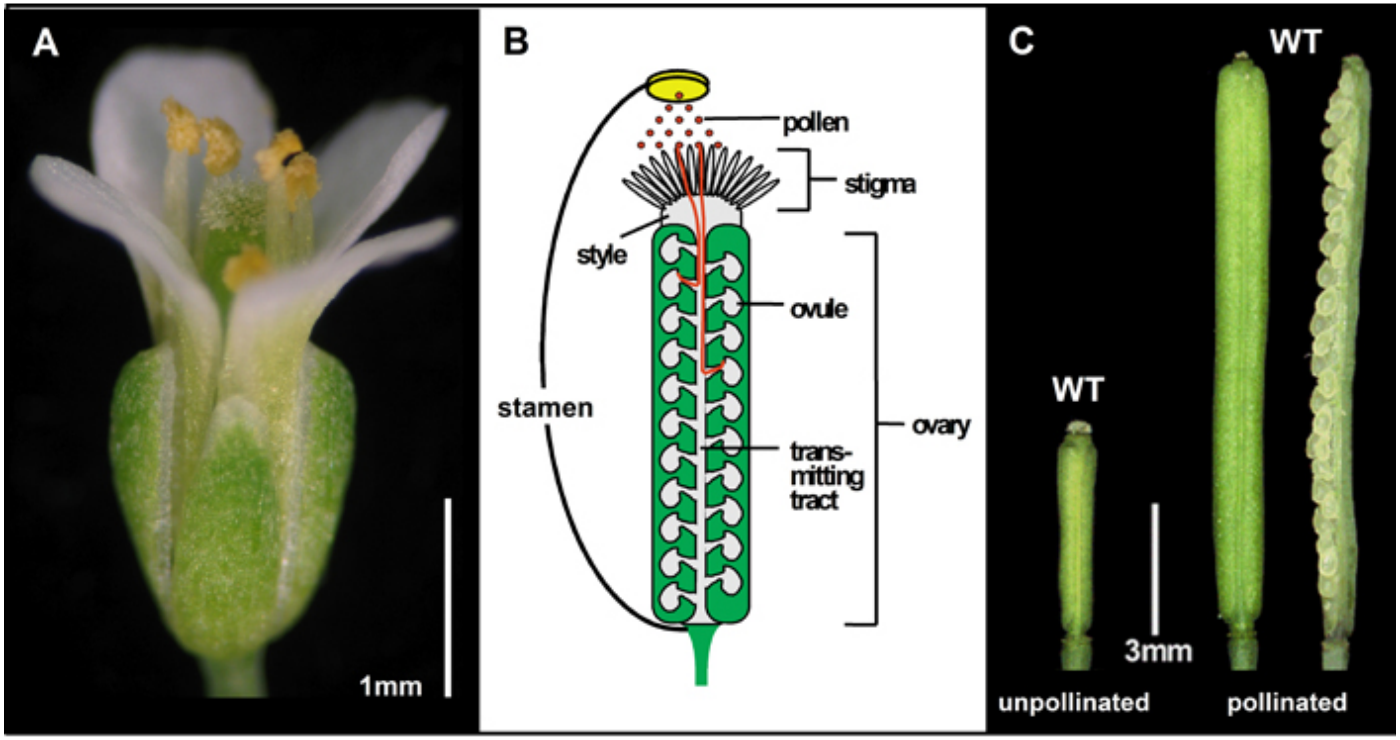
Fertilized 3n
→ Endosperm for nutrition

Integuments of ovule

Mother tissue origin

→ Seed coat

Mainly maternal control ?

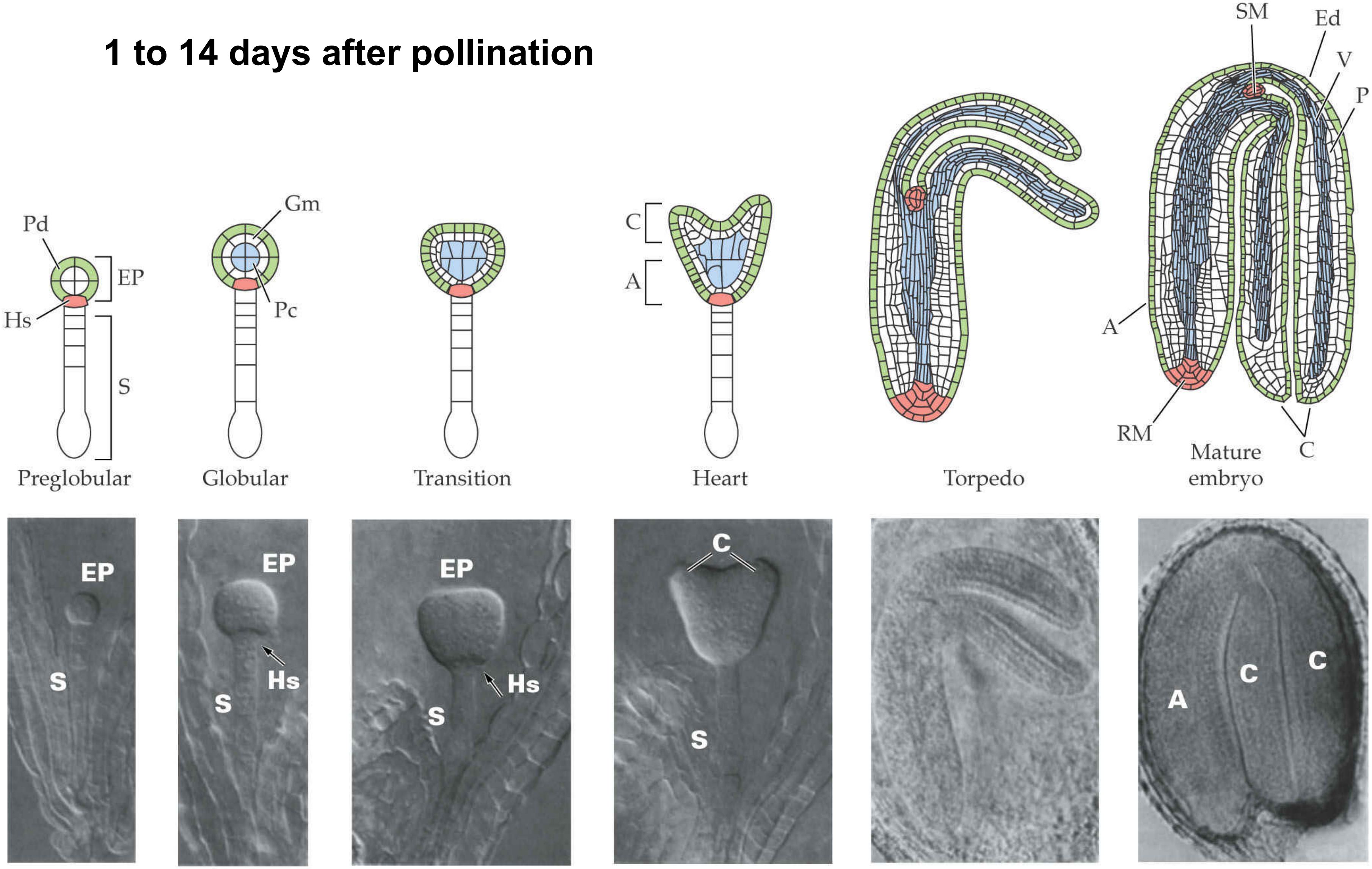


A) Open Arabidopsis flower at anthesis (pollen shedding). The sepals (green) partly enclose the petals (white), the stamens (yellow anthers, *top*), and the central gynoecium consisting of the stigma, style, and ovary. The anthers have just begun to deposit pollen onto the stigma.

B) B) Normal Arabidopsis flower with sepals and petals removed. Mostly self-pollinating, pollen grains produced by the anther germinate on the stigma to produce pollen tubes (shown in red) containing two sperm cells that grow through the transmitting tract toward the ovules. Once a pollen tube reaches an ovule it enters inside and into the female gametophyte where it releases the sperm cells.

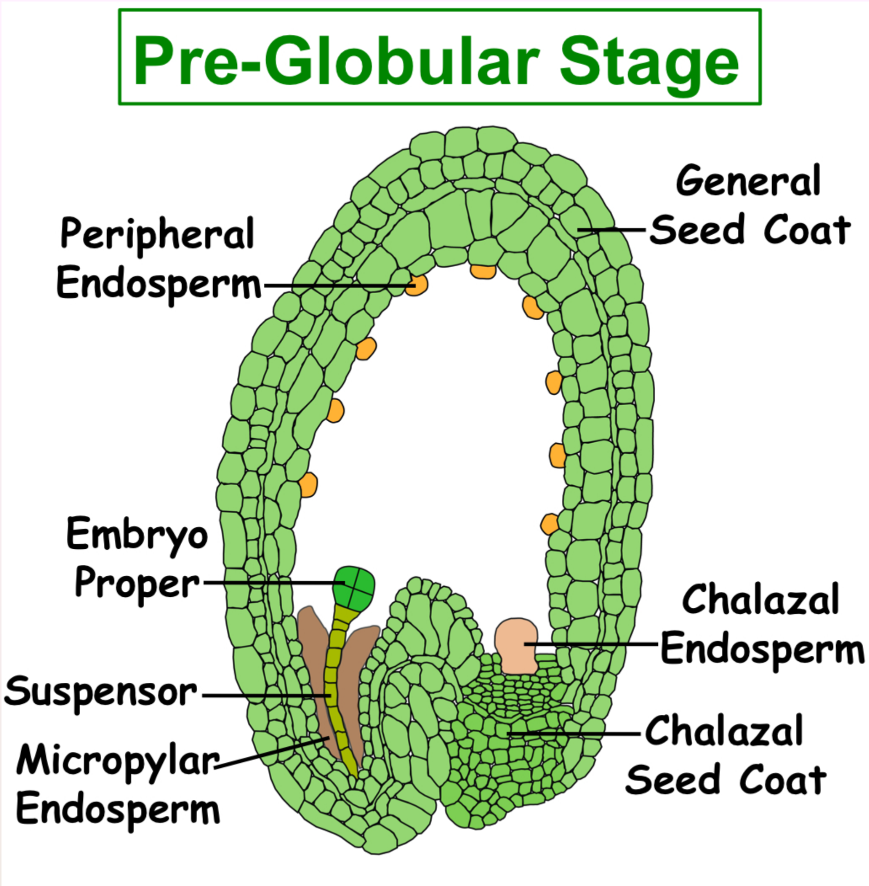
C) Double fertilization occurs as one sperm cell fuses with the egg cell to initiate embryo formation and the other fuses with the central cell nuclei to initiate endosperm development. At this point, seed set occurs and as embryo and endosperm development proceed, the surrounding ovule tissues differentiate into a seed coat. C) The gynoecium of unpollinated WT flowers (*left*) in which no seed set occurs, exhibit little growth beyond the stage shown in (A). Pollination and seed set promote fruit initiation and subsequent growth.

1 to 14 days after pollination

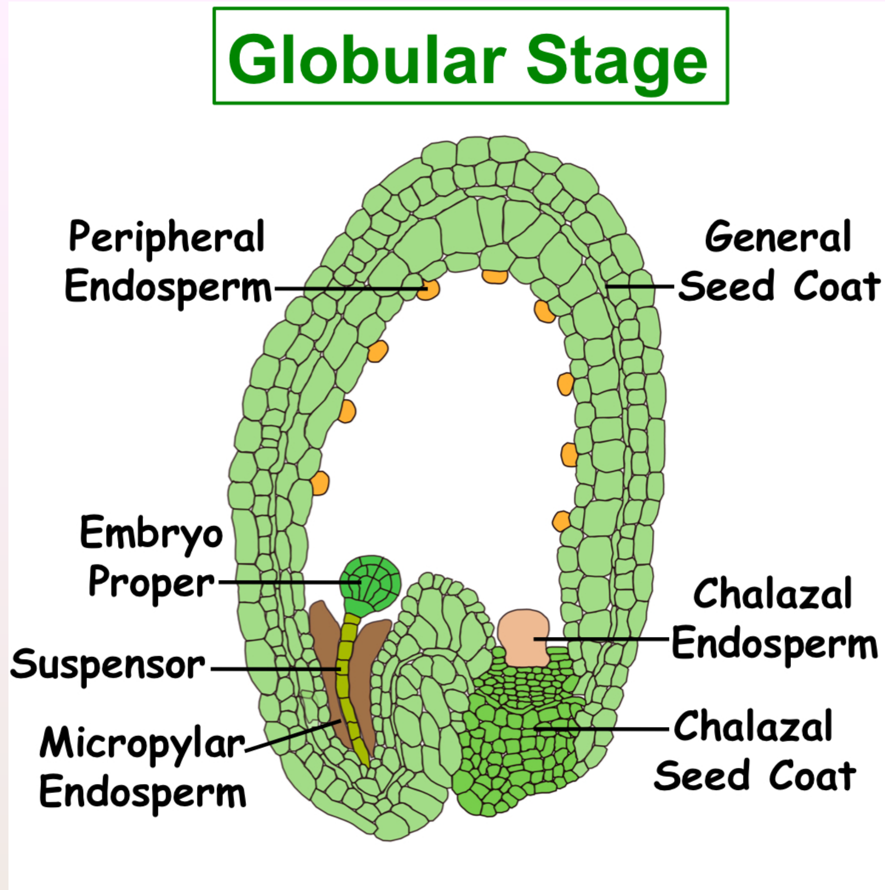


STAGES of SEED DEVELOPMENT IN ARABIDOPSIS (think ca

2 days

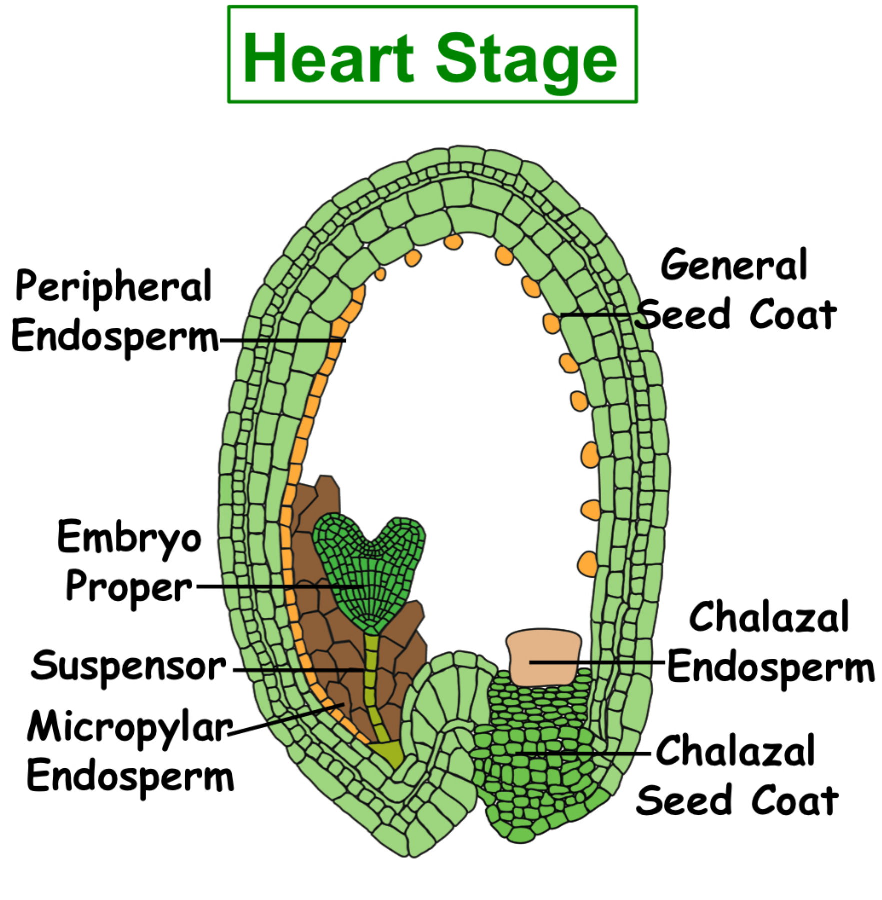


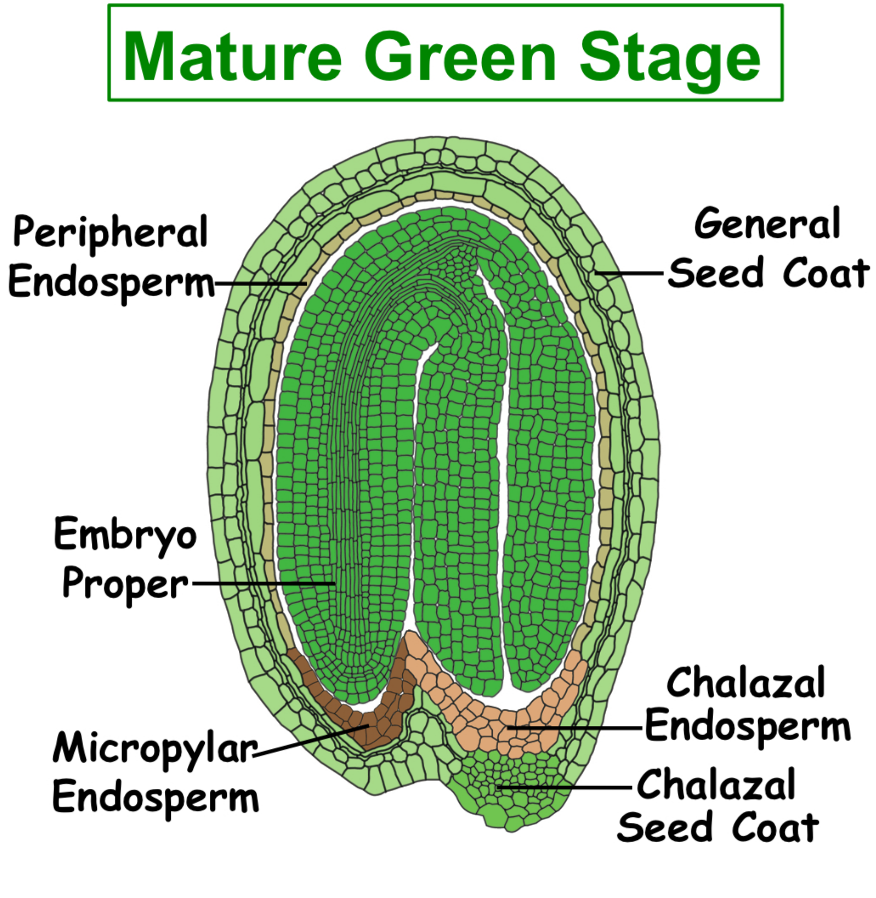
4 days



ARABIDOPSIS – BUT THINK CANOLA
Diagrams by Meryl Hashimoto
Seed Gene Network
(Goldberg and Harada, UCLA and UC Davis, USA)

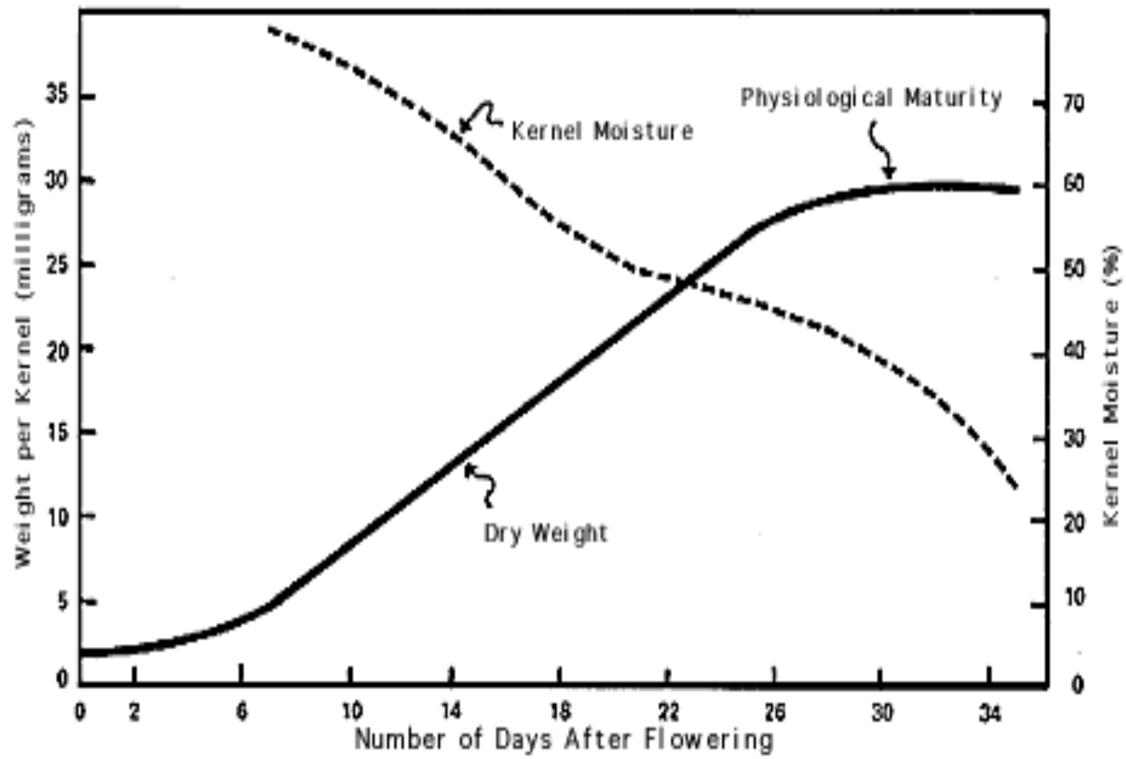
6 days **14 days**

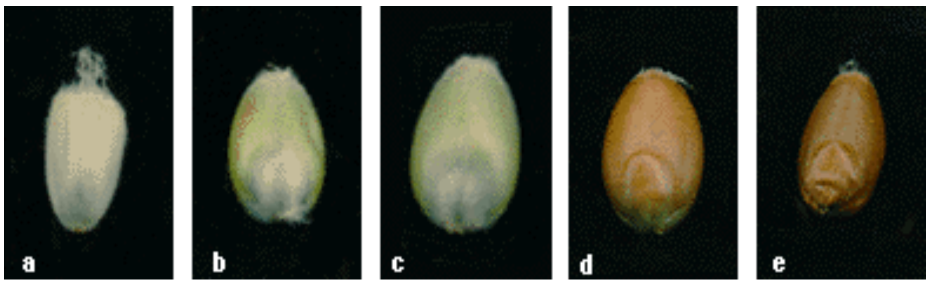




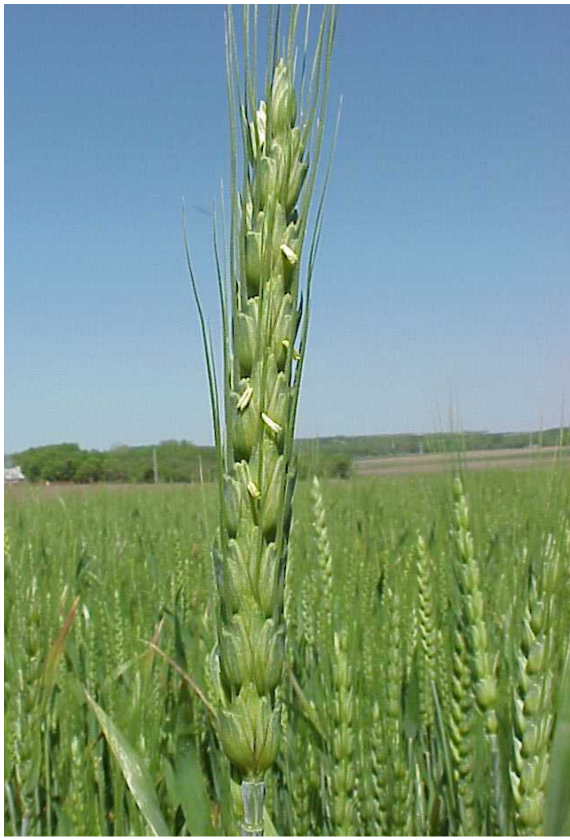
Followed by ripening, seed coat color change then desiccation

KERNEL GROWTH IN A CEREAL - WHEAT





Z 6.5
Anthesis half way



Winter wheat, Kansas State Univ. Jim Shroyer, Extension

Open floret (flower) from a spikelet, middle of inflorescence (head)

Anthers shedding pollen on stigma

Developing kernels of winter wheat

1 to 7 days old

1 to 10 days old

Cell division determines tissues of the seed, seed size

At 10 days we are almost at the final grain length (seed size)

15-17 days old

Milk stage

20 days old
late milk

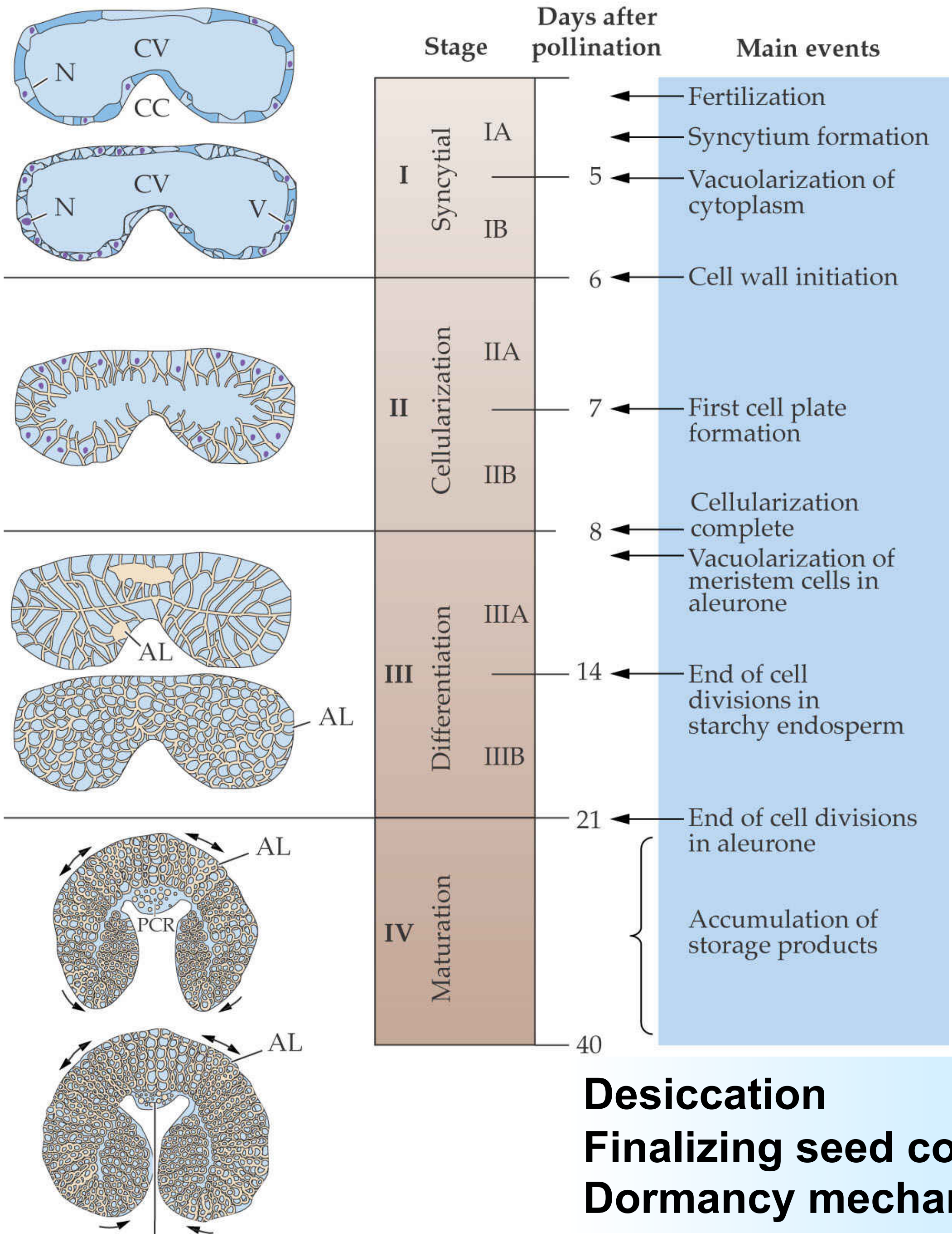
Kernel has watery liquid
and white material,
the beginning of
starch metabolism
in the endosperm

soft dough

early hard dough

hard dough

physiological maturity



Pollination and fertilization

Cell division

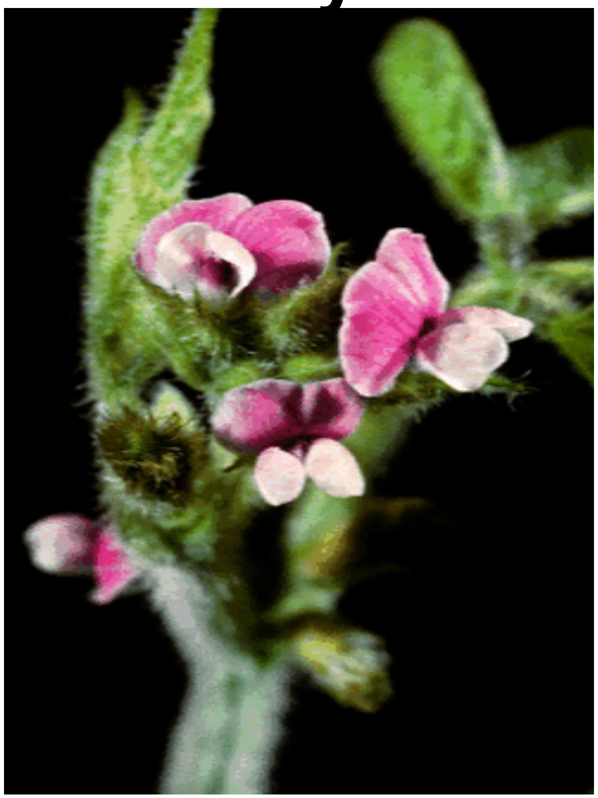
seed size likely determined by now

End of division in endosperm followed by aleurone

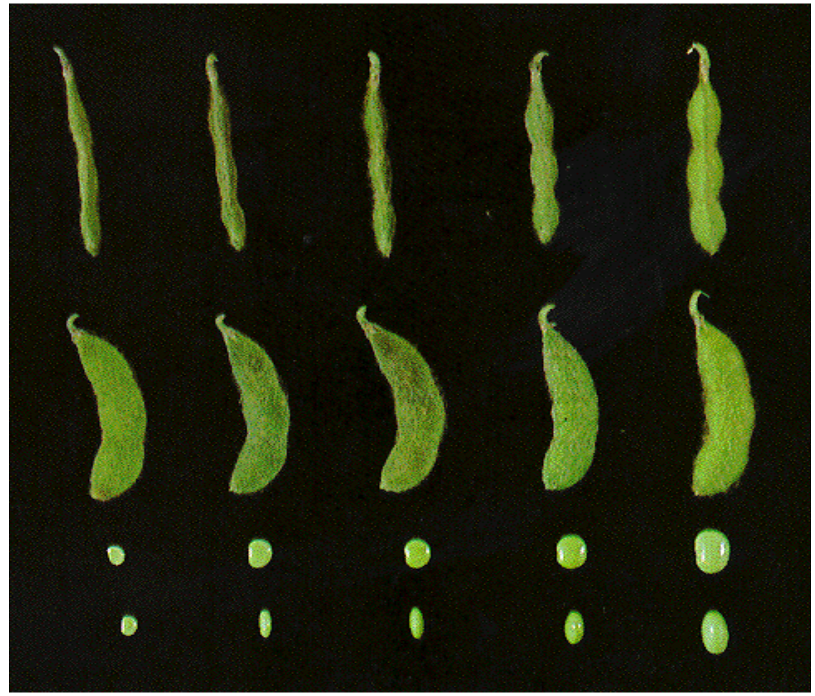
Accumulation of storage products
Sugars (hexose)
Amino acid metabolism followed by starch

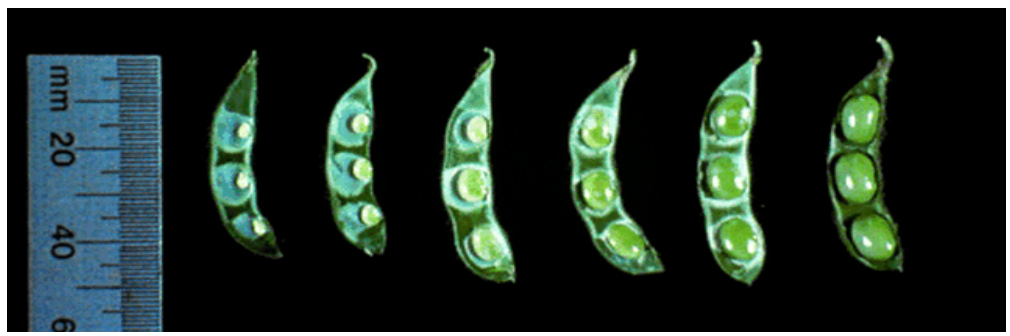
Desiccation
Finalizing seed coat
Dormancy mechanisms if used by spp.

Seed development in Soybean



R2 full flower





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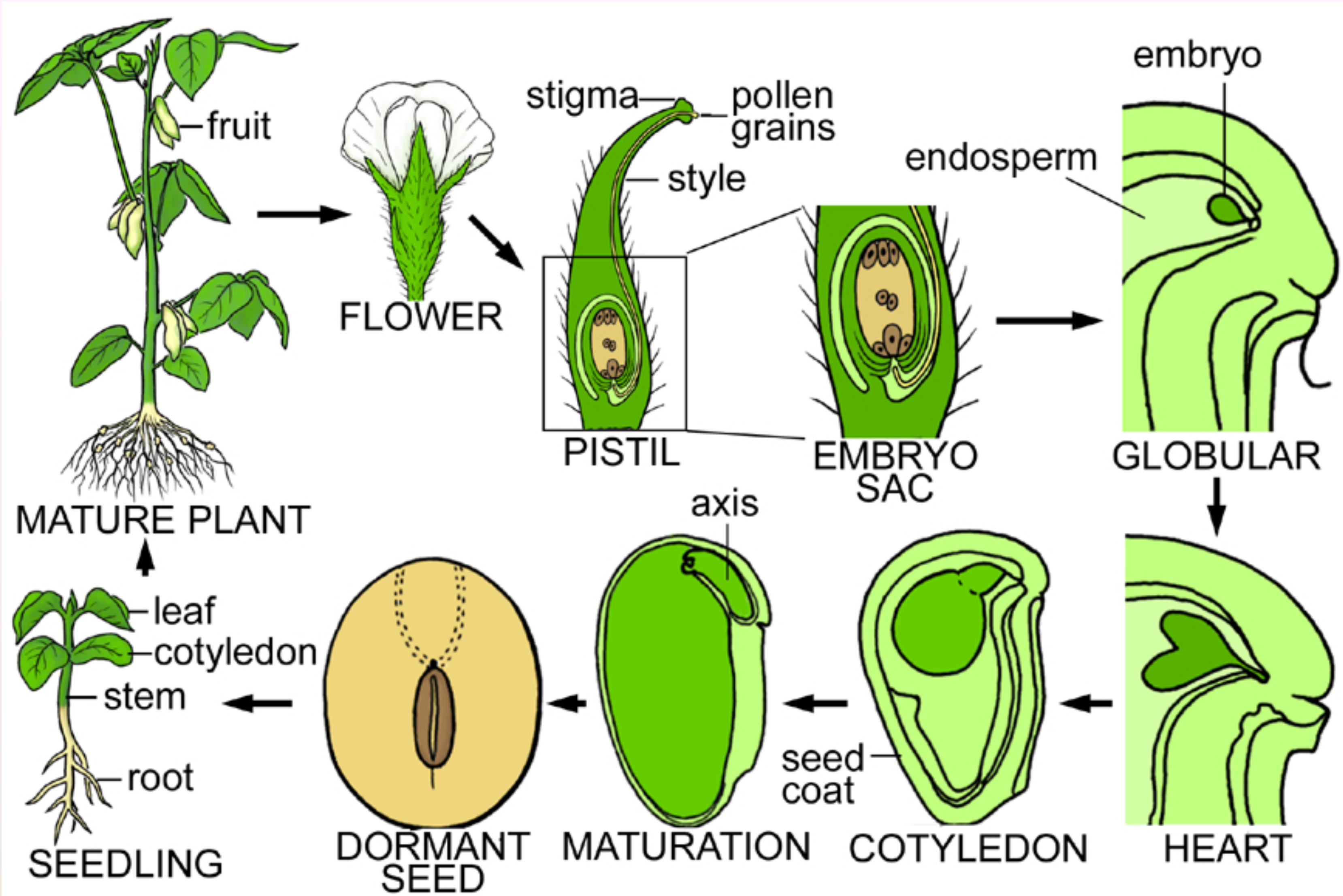
beg. fill linear fill

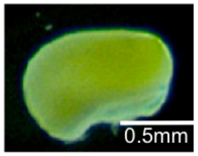
end fill

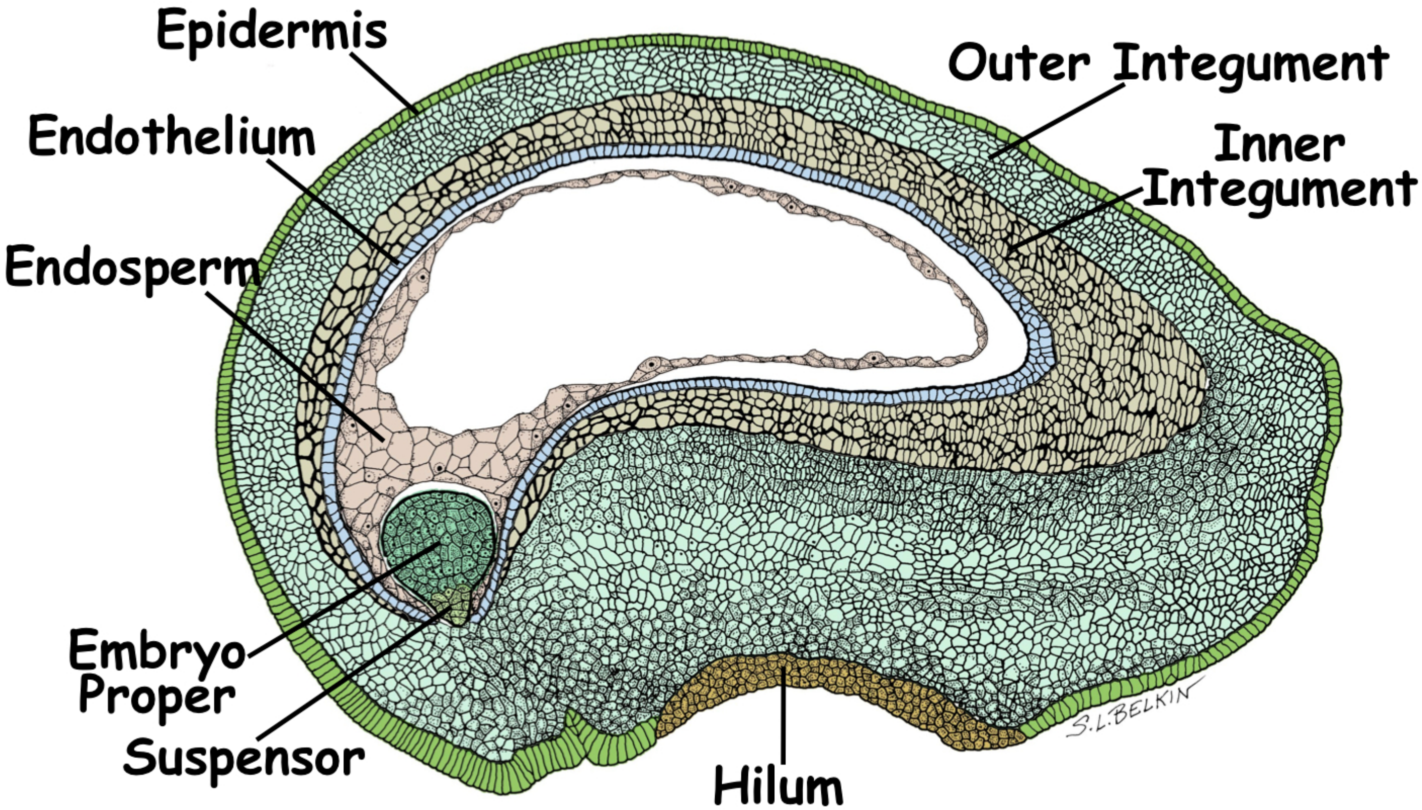
SOYBEAN



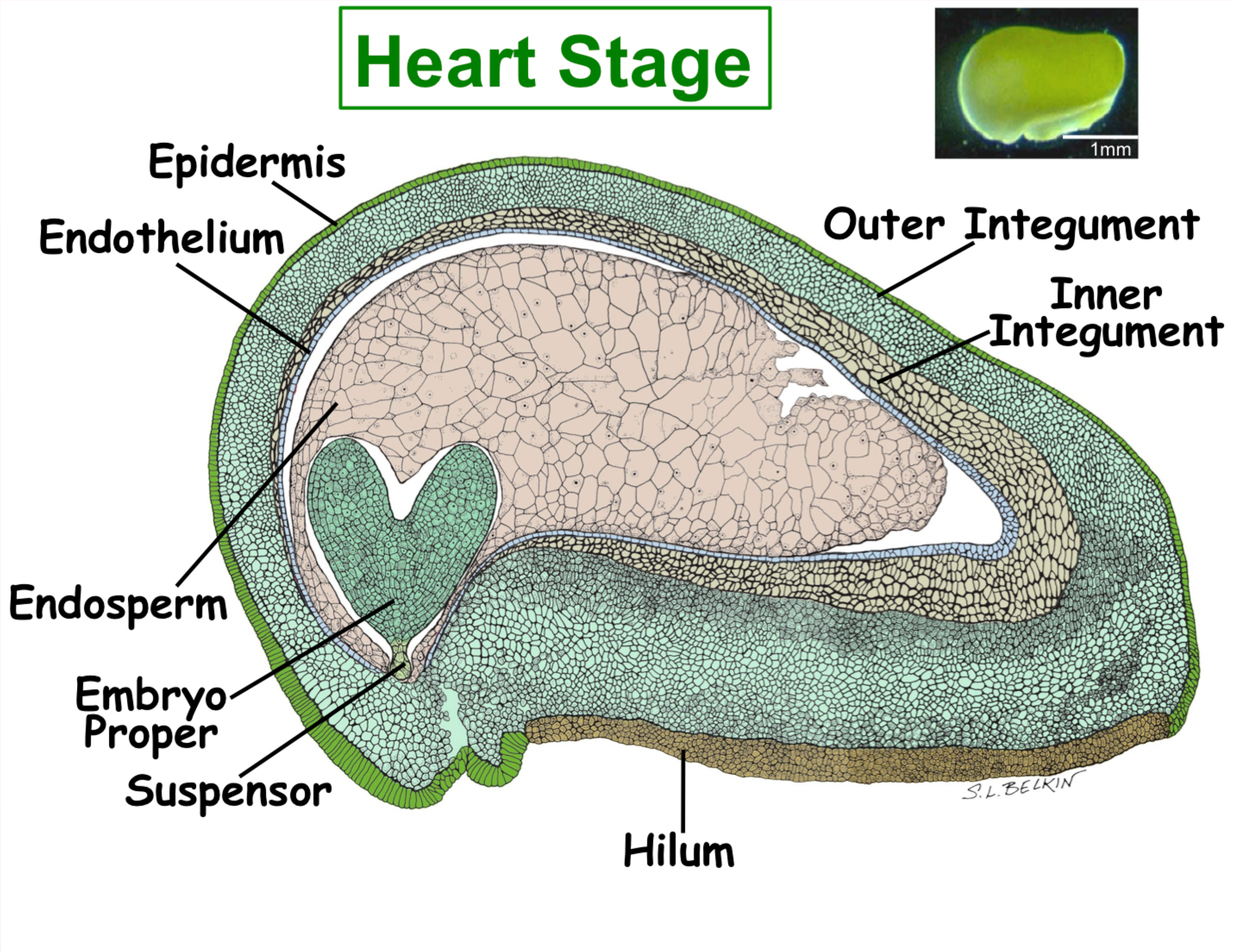
Seed Gene Network (Goldberg & Harada, UCLA and UC Davis, USA) Drawings - Sharon Lee Belkin

Globular Stage



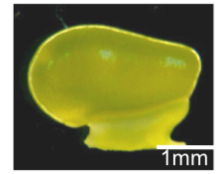


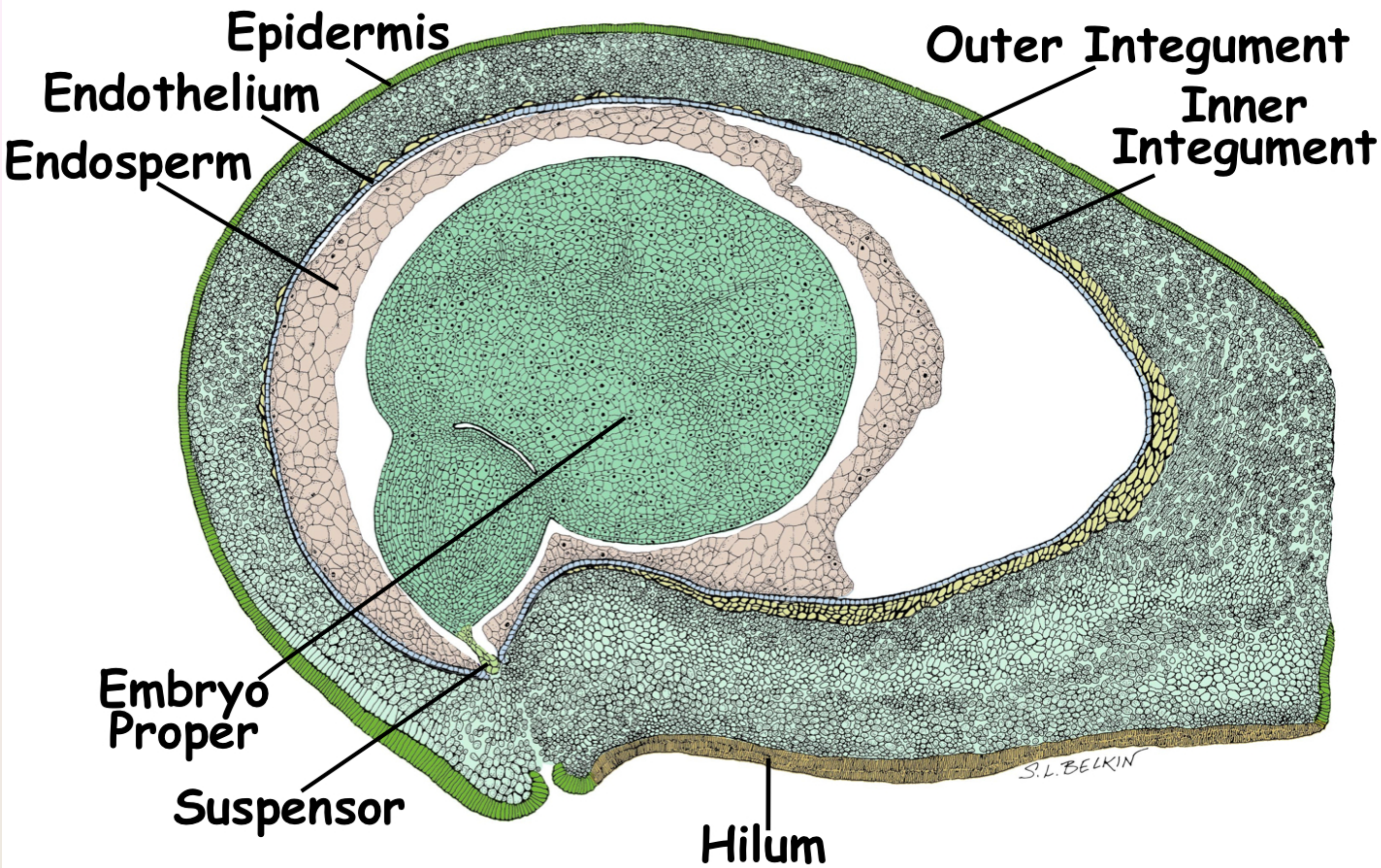
5 days after flowering



15 days after flowering

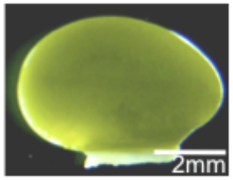
Cotyledon Stage

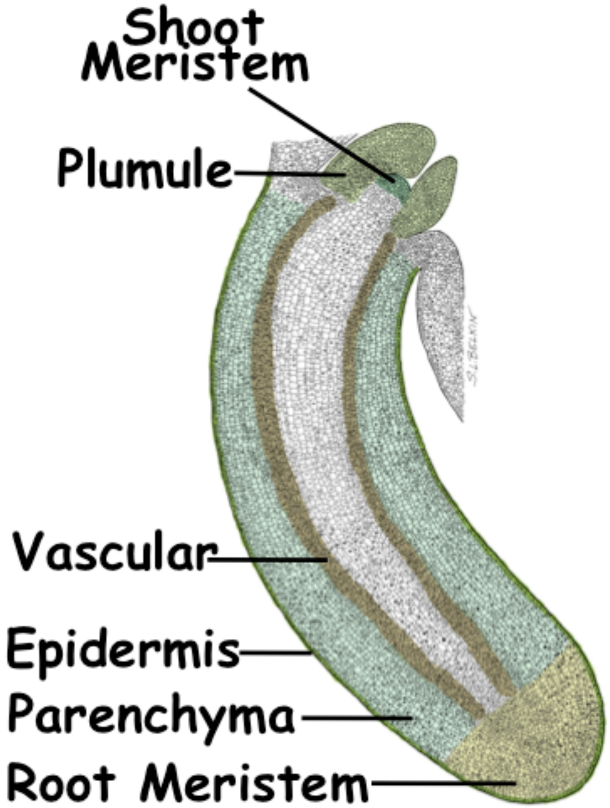


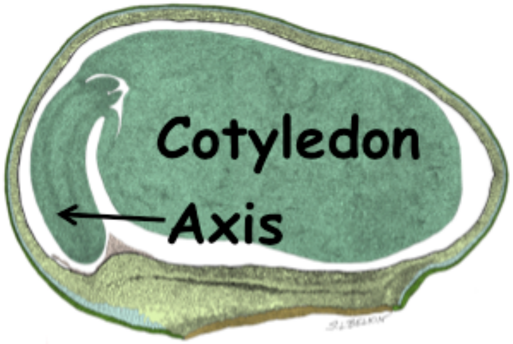


25 days after flowering

Early Maturation Stage

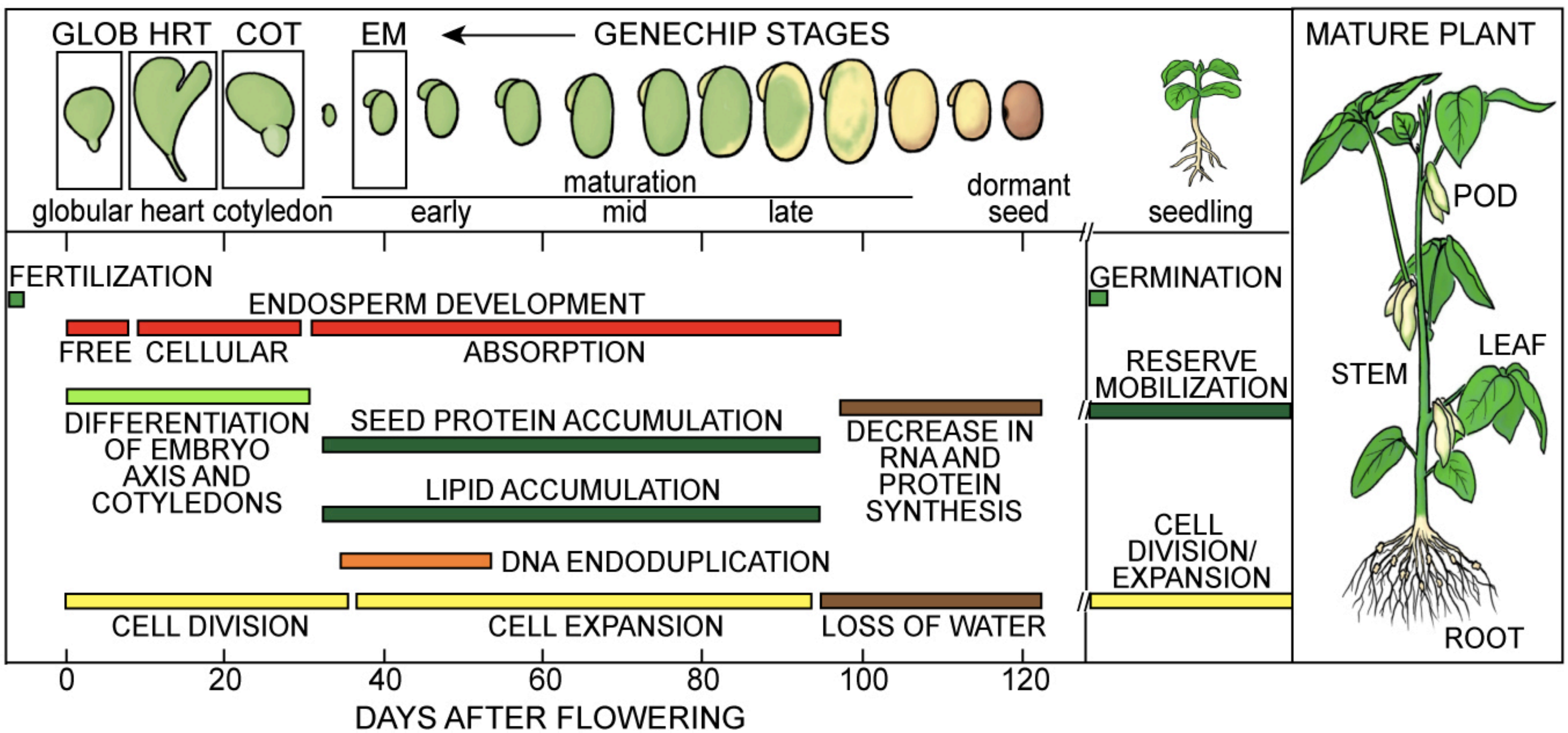






40 days after flowering
Seed can now start filling

Axis



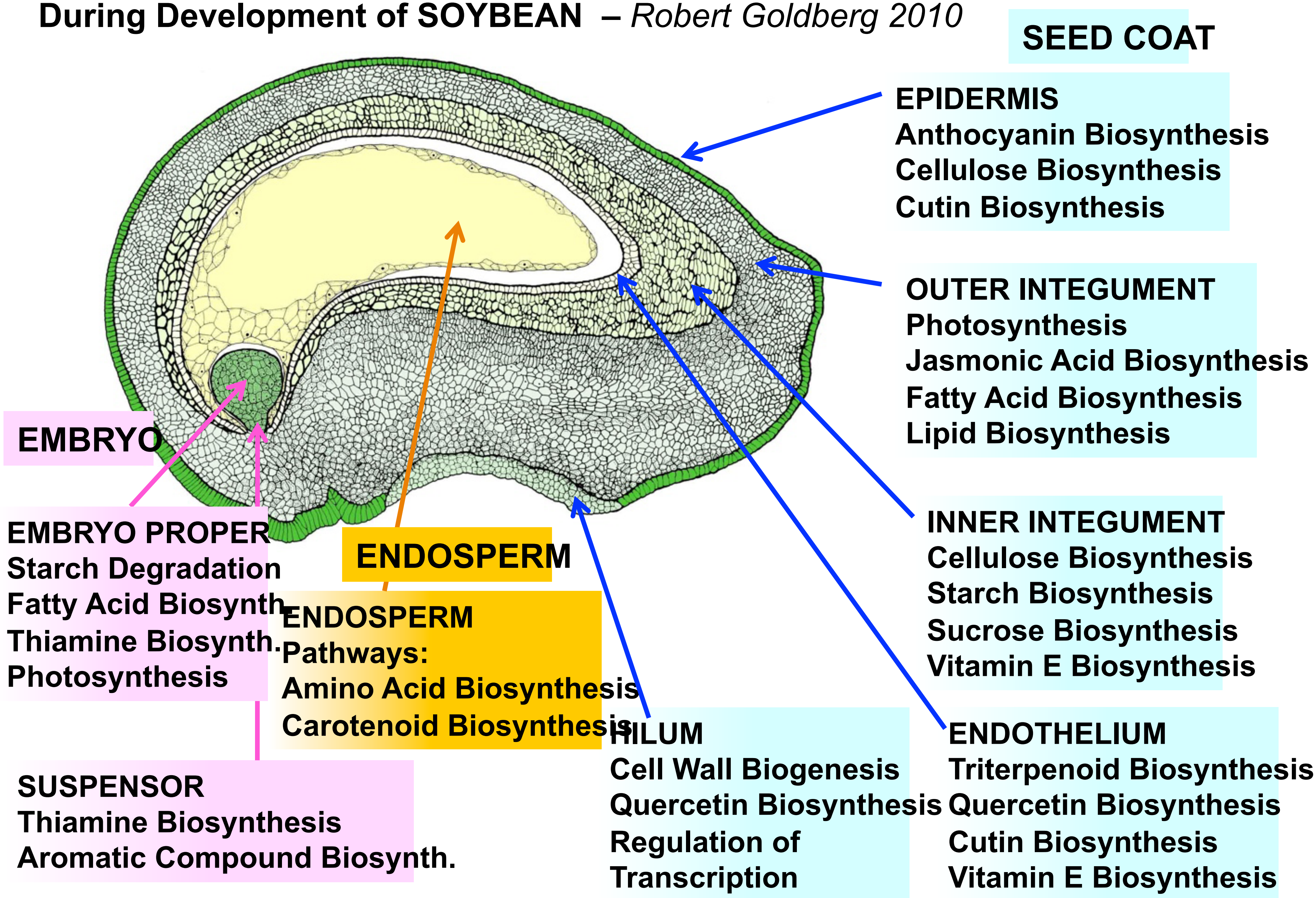
Differentiation of compartments, tissues and regions

Storage protein & starch deposition preparation or dormancy

Desiccation & preparation for dormancy

Dormancy then germination

Functional & Regulatory Specialization of Seed Compartments During Development of SOYBEAN – *Robert Goldberg 2010*



SOYBEAN SEED GROWTH IS COMPLEX AND REGULATED – Robert Goldberg 20

Globular embryo to mature seed

Suspens-or	Embryo	Endo-sperm	Endo-thelium	Inner integ	Outer integ	Epi-dermis	Hylum

26,000 diverse mRNAs are required to program seed development

15,000 diverse mRNAs in each seed compartment, region, and/or tissue
22,000- 24,000 diverse mRNAs are present in a seed as a whole
these are the genes required to "make a seed" (½ the genome)

Most mRNAs shared by different compartments, regions and tissues -- many are quantitatively regulated

Each compartment, region and tissue has small (10-90) set of "specific" mRNAs, including those encoding transcription factor mRNAs

Sequences beginning to be identified that activate transcription in different seed regions - TIMING or WHEN THINGS ARE SWITCHED ON AND OFF

Seed Gene Network (Quoting Goldberg from Goldberg & Harada, UCLA and UC Davis, USA)

PHYSIOLOGY OF SEED SIZE

Soybean

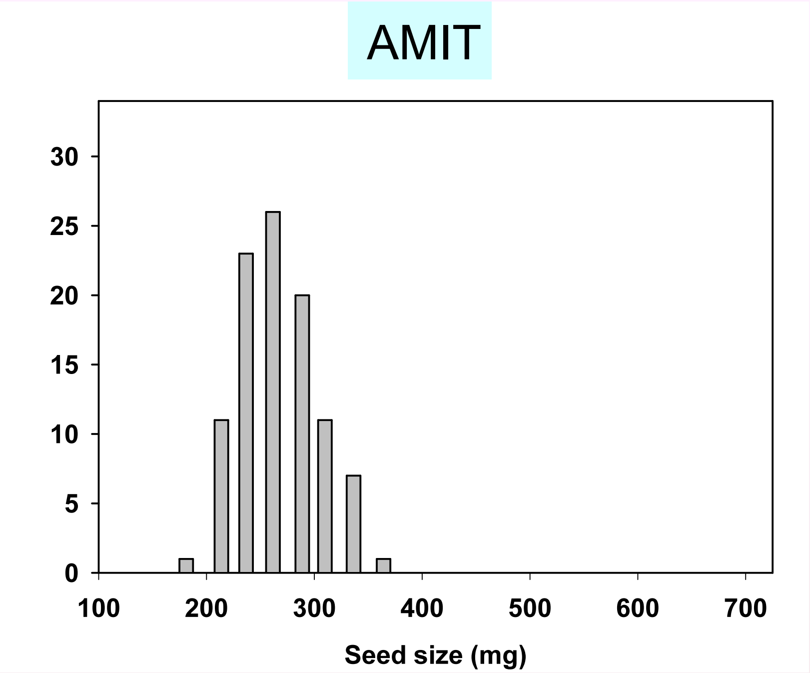
Chickpea

Genetics dictates an inherited seed size

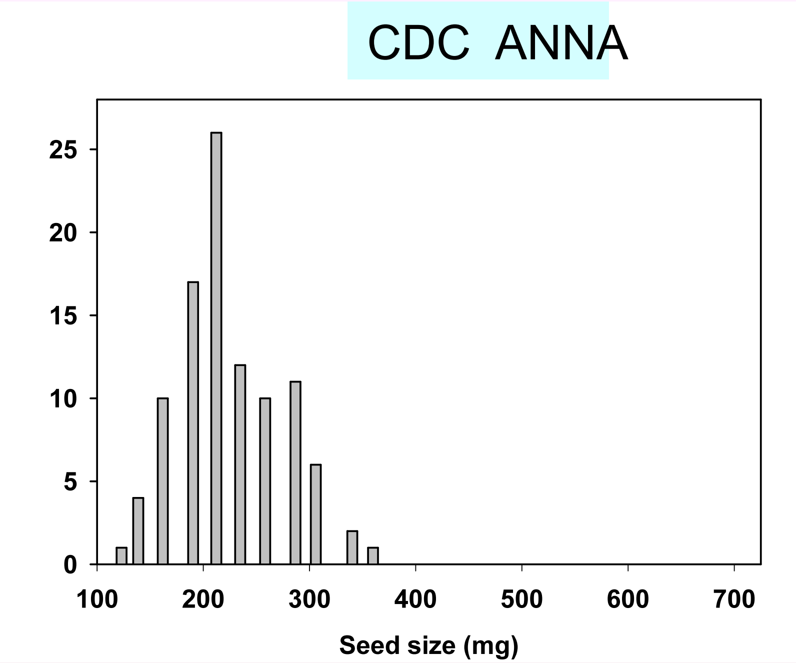
In reality - mostly that seed size
The environment dictates a range of seed size

Average seed size varies in a narrow range
Plant compensates to conserve seed size

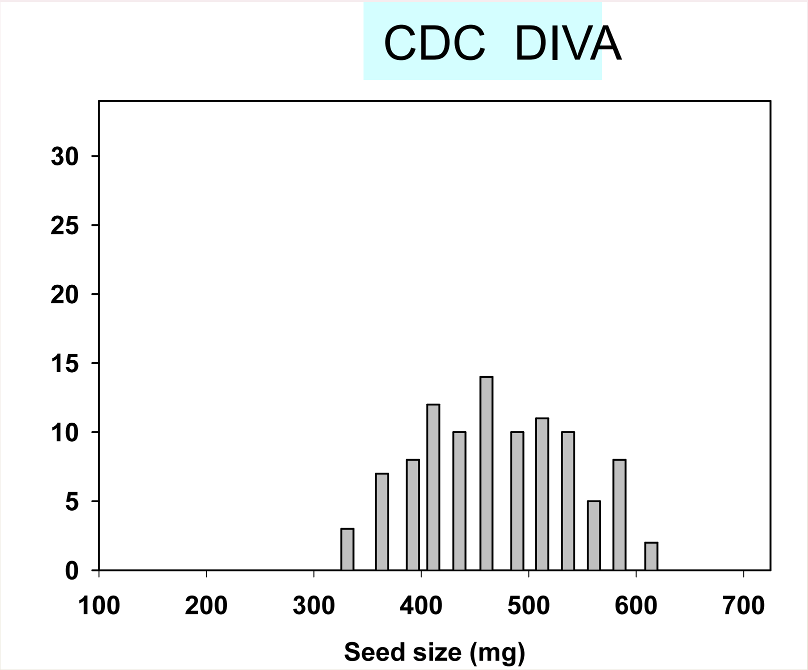
Why are the seeds not the same size?



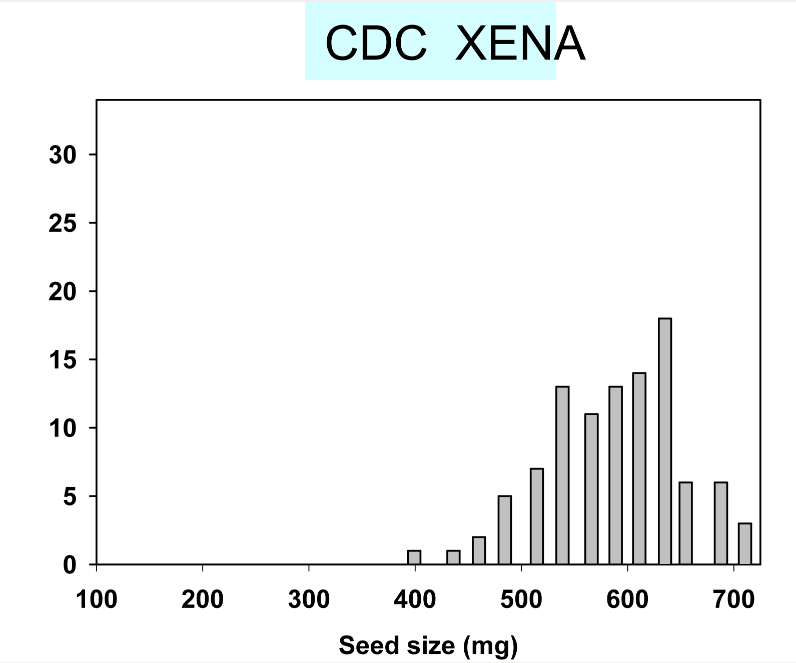
AMIT
30
25
20
15
10
5
0
100
200
300
400
500
600
700
Seed size (mg)



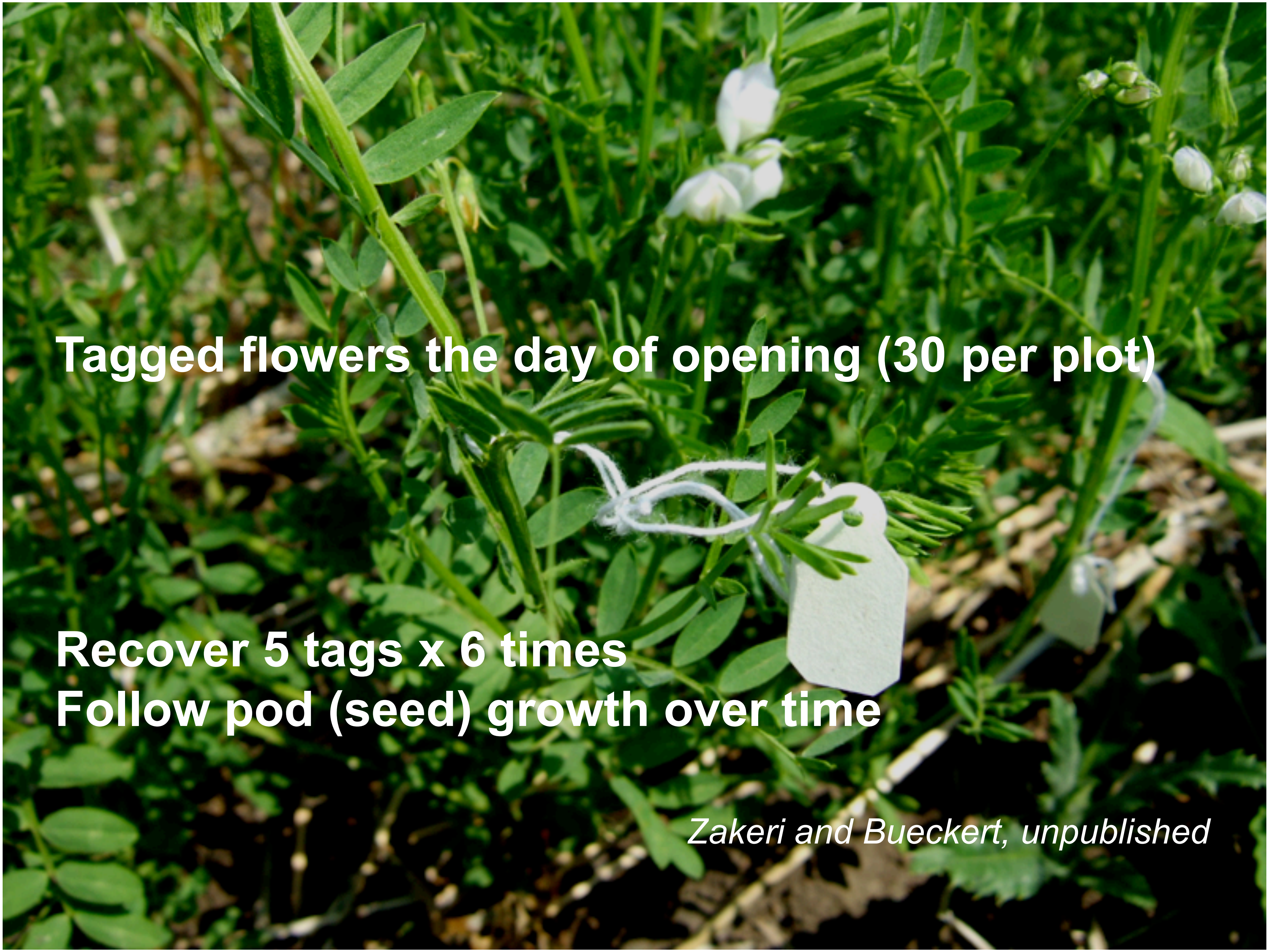
CDC ANNA
25
20
15
10
5
0
100
200
300
400
500
600
700
Seed size (mg)



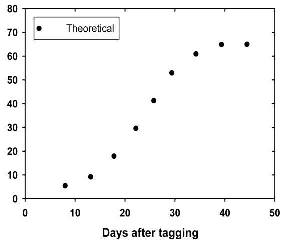
CDC DIVA
30
25
20
15
10
5
0
100
200
300
400
500
600
700
Seed size (mg)

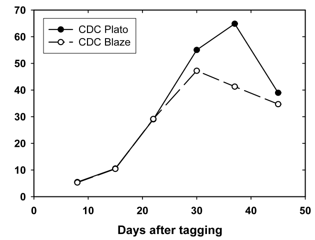


CDC XENA
30
25
20
15
10
5
0
100
200
300
400
500
600
700
Seed size (mg)


Tagged flowers the day of opening (30 per plot)
Recover 5 tags x 6 times
Follow pod (seed) growth over time
Zakeri and Bueckert, unpublished

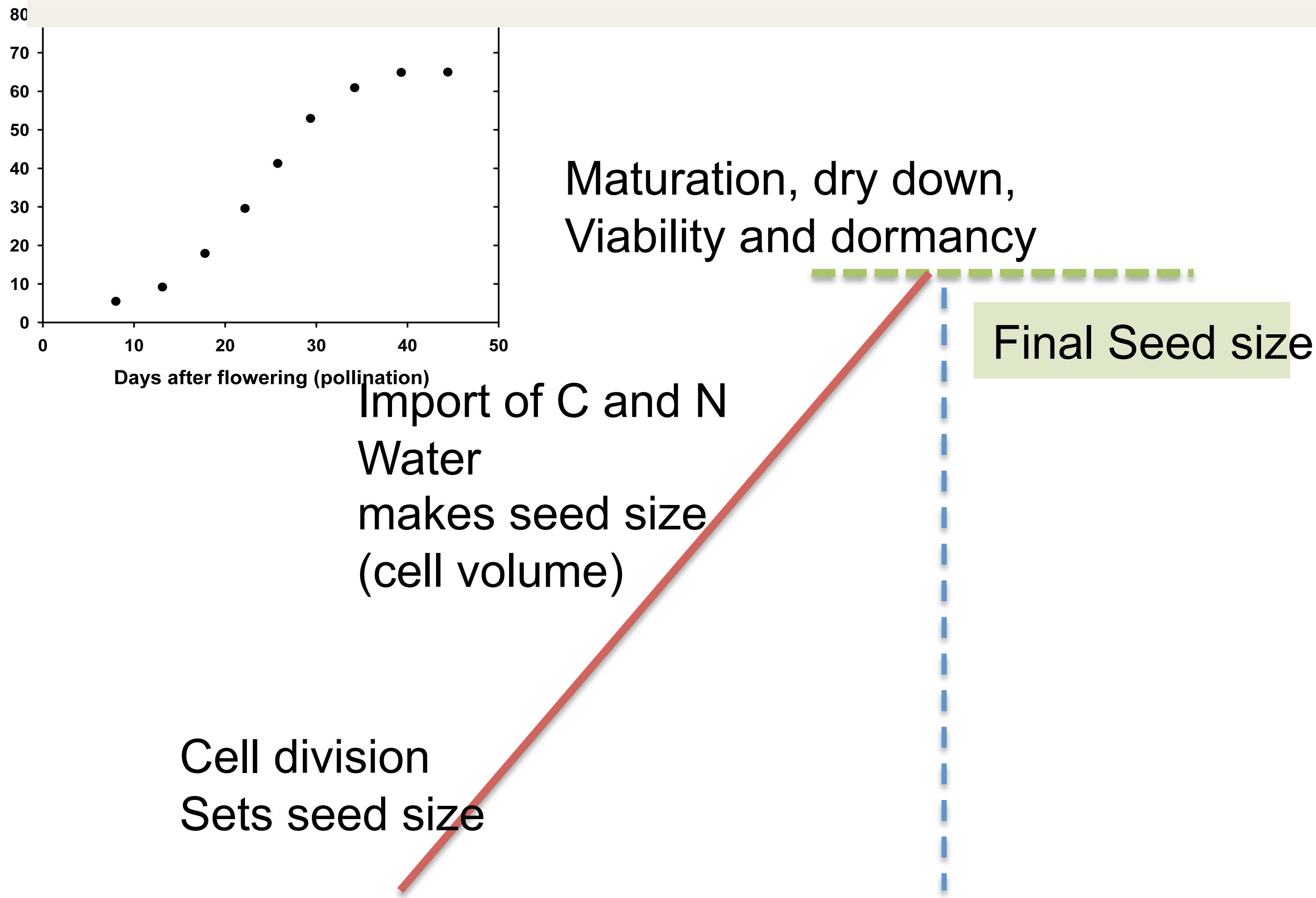
FOLLOWING POD DEVELOPMENT FROM TAGGED PODS



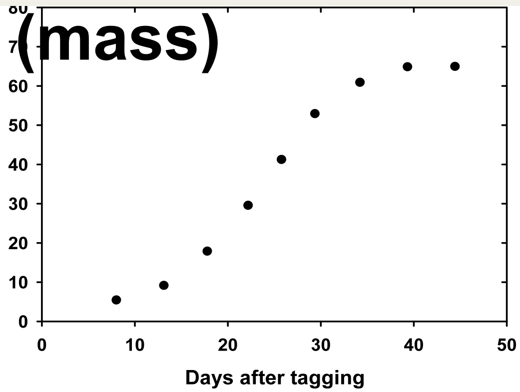


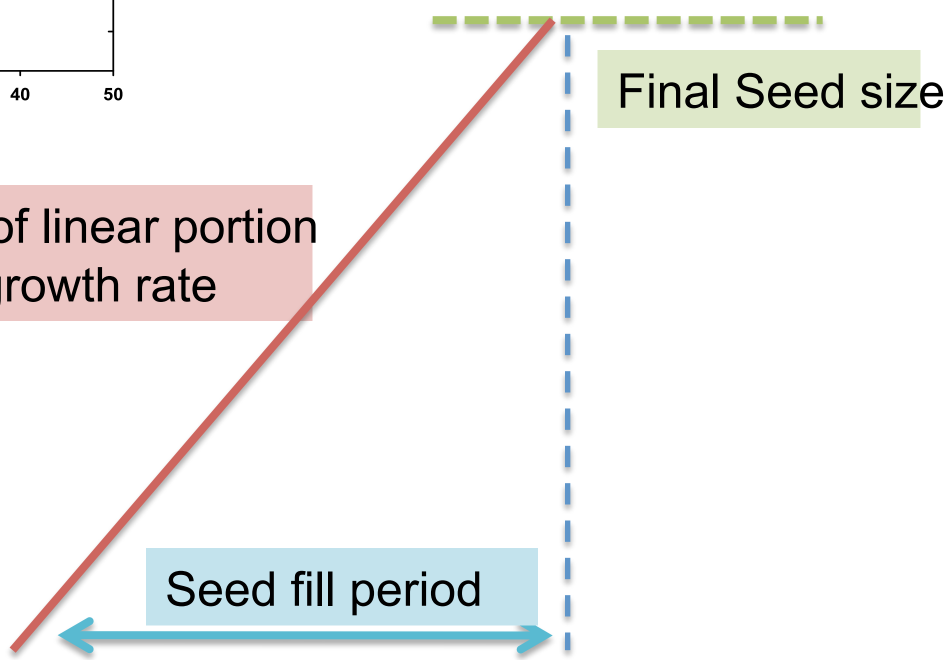
Actual data

HOW A SEED GROWS



SEED GROWTH
Seed growth rate, seed fill period, final seed size (mass)





OVER ALL CROPS

Big seeds
more cells
high SGR
so fill in time

Small seeds
low SGR
fill in short time
lots of them

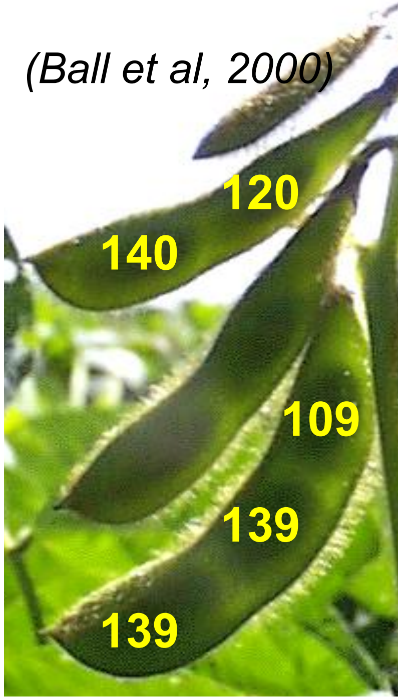
Egli, Univ Kentucky

SOYBEAN SEED SIZE

Range of plant population densities
Seed (mg) from two and three-seeded pods

Distal seeds conserved,
Seed closest to peduncle aborted or smaller
Fill period conserved (25 to 31 days)

(Ball et al, 2000)



Growth of individual seeds on field plants
average seed size = 130 mg

The more seeds per plant, seeds are smaller
Big plants, large range of seed number, smallest range of seed mass (35 mg
Small plants, small range of seed number, large range of seed mass (100 mg

(Spaeth and Sinclair, 1984)

PHASEOLUS BEAN SEED SIZ

Andean bean (cooler region) – larger seed
Meso-american bean (warmer) – smaller seed

Cell number, cell volume, seed growth rate

Bigger seed have more cells, cells are larger, SGR greater

Andean: have larger cells and greater SGR
Grow Andean at a warm site, small seed, less cells, same cell volume and SGR

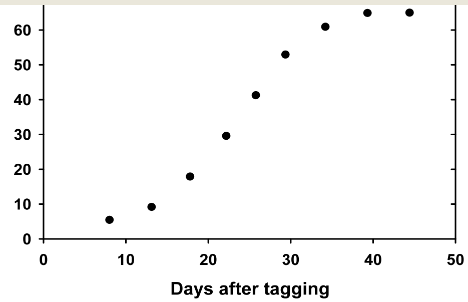
Cell division is ultimately determining seed size

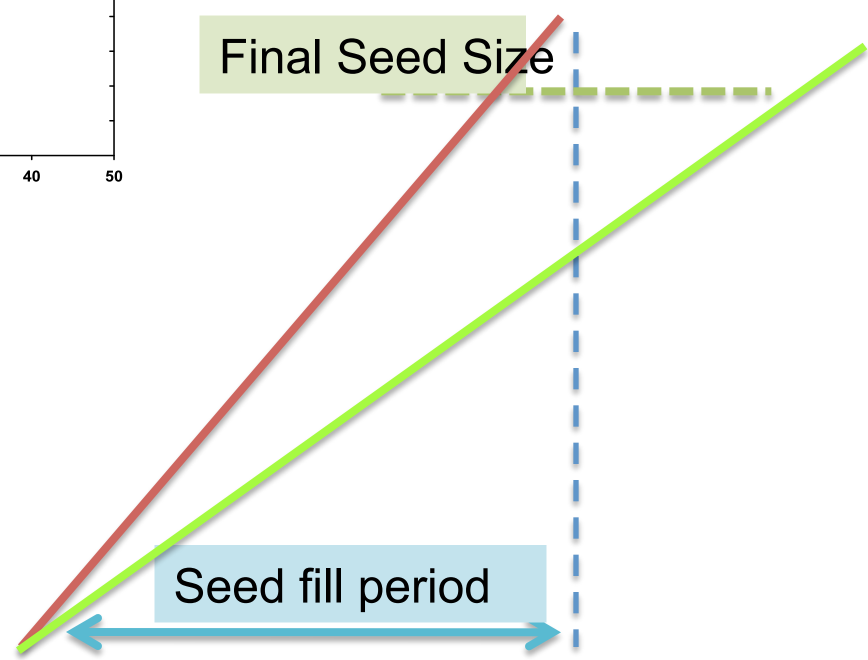
Sexton et al, 1997
Photo: Paul Gepts

SEED GROWTH IN STRESS

Seed growth rate is lower, fill period needs to be longer to achieve final seed size

Reality : smaller seed with lower vigor
lower SGR, same fill period = smaller seed





SEED SIZE REGULATION

Seed size is inherited

Balance of cell division and resources (photosynthesis of plant)

Two cultivars, same yield:

A has more small seed,   B has less but larger seed

Cell division before linear seed fill determines seed size

* ***The growth potential of the 'early seed coat'*** *

Local maternal control of seed size by a cytochrome gene (regulator):

this is limiting in the flower (ovule integuments), but expression in the inner or outer integument promotes seed growth, and cell division. The amount of cell proliferation in the integuments controls seed size.

(Lenhard, Adamski et al, 2009 - John Innes Inst. UK)

Obtained lots of small seed vs less larger seed but the same 'yield'

Size is an advantage

- Larger cotyledons (dicot) or endosperm (cereals, grasses)
- Larger embryo (bigger stem /coleoptile and leaves) at emergence, larger seminal roots
- Greater seed store for germination under good and adverse conditions
- For the same year and cultivar, larger average seed size indicates better growing conditions and more seed are at maximum genetic size
- Hybrids – larger seed than conventional varieties
- **Larger seed produce a more vigorous stand**

Photo: Tom Warkentin, CDC, U of S

Questions? Comments?

LITERATURE

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Ball et al 2000 Crop Sci 40:1070

Buchannan et al 2000   Biochemistry & Molecular Biology of Plants

Egli 1998 Seed Biology and the Yield of Grain Crops, CAB International

Goldberg and Harada 2011 http://seedgenenetwork.net (view the media material)

Sexton et al 1997 Field Crops research 54:163

Spaeth and Sinclair 1984 Agronomy Journal 76:128

Taiz and Zeiger 2002 Plant Physiology (3rd Edition)

Photo: Tom Warkentin, CDC, U of S

Dormancy – or lack thereof

Most crops have no or minimal dormancy
Dormancy achieved in seed fill (protein),
or late-fill to dry down (chemical, seed coat, just desiccation)
Pre-germination by premature water uptake (around grain maturity, storage)

Resistant:
Large day /night temperature amplitude near end of grain fill / maturity

Susceptible to sprouting:
Growth of zero-dormancy crops in 7.5 to 15 °C plus 3 days rain
or high humidity n
Water uptake is irreversible
Lower vigor

Breaking dormancy
Seed coat –nick coat
ABA and phenolics –leach out
GA applications
Temperature jumps